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Exploring Making Through Mobile Emergent Technologies: Makerspace Education in Rural Communities

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Table of Contents

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Introduction

The Obstacle

Little research has explored the role of science, technology, engineering, and math (STEM) or makerspace education in rural communities, despite the fact that 11.4 million children in the United States grow up in rural communities and one-third of U.S. public schools are rural (Strange et al., 2012; Williams, 2010). Recent studies showed that rural students are increasingly likely to attend college (Byun et al., 2010; Meece et al., 2013), yet are also less likely to graduate from college programs (Peterson et al., 2015).

Across the country, rural communities are rethinking how they can both support their local economy and provide more opportunities for young people. Many manufacturing companies in rural regions are desperate for engineers and skilled employees who are STEM literate. Recruiting qualified personnel is challenging, and rural communities experience pressure to "grow their own" STEM workforces. A survey conducted in the Wausau, Wisconsin area with six local major employers who hire software developer-related occupations revealed that when companies require job applicants to have degrees in a computer-related field, there is a dearth of qualified candidates. At the same time, area high schools struggle to get students to think of themselves as potential members of the technical, computational, or manufacturing workforce (Alcoa Foundation, n.d.; Croff, 2017; Jaschik, 2015). Young people have limited access to STEM and computational skills beyond the job training available for work on the factory floor. Without some type of intervention, rural students may be less likely to pursue jobs in engineering (Elam et al., 2012) that can lead to more high-tech and high-level positions in manufacturing companies.

Our Approach

The Exploring Making Through Mobile Emergent Technologies (EMMET) program sought to disrupt the trajectory from rural high school to factory floor by introducing STEM and computational thinking (STEM+C) skills through mentorship training and hands-on activities involving creative production—often referred to as "making." The program also bridged the divide between formal school science education and informal opportunities for science learning outside of school—a division that has marginalized young people from science class and devalued everyday science experiences (Stocklmayer et al., 2010).

The overall project focused on designing maker experiences, training local high school students as "maker-mentors" for their community, developing partnerships with area community-based organizations, and researching what program participants learn about STEM and computational thinking. The work described in this white paper offers a model for regions with distributed, rural populations to build capacity for young people to develop skills and self-efficacy in STEM+C fields.

This paper aims to answer the following questions:

1. How are rural communities impacted by mobile making experiences that involve community mentors as instructors?
2. What do maker-mentors learn as a result of their participation in facilitating mobile making experiences?
3. What aspects of the community-involved maker experiences are sustained beyond institutional intervention?

Key Findings and Data Sources

Key findings are based on eight sources of qualitative data gathered throughout the three years of the program:

- preliminary interest surveys from 20 maker-mentors
- observations and field notes from maker-mentor trainings and facilitation events
- interviews with maker-mentors throughout the program
- video and audio recordings of maker-mentors talking about their learning and co-making
- photos from trainings and facilitation events
- maker-mentor post-event reflections
- learner written responses gathered at the Wausau Science & Engineering Festival
- agenda notes and bookkeeping documents

High-Level Takeaways

This study revealed three major findings related to our research questions.

Finding 1: Mobile making experiences offered co-learning opportunities for young people and their families, sparked learners' curiosity, allowed for interest-driven discovery, and created a pathway to scientific thinking.

Finding 2: Maker-mentors learned how to use new tools and to repurpose materials; to realize the value of STEM+C for society and for their future careers; and to break down problems into smaller parts. Maker-mentors improved their collaborative and communication skills and became better teachers. They learned more about themselves by taking on identities as learners and by participating as collaborators.

Finding 3: Northcentral Technical College, which served as the hub for this project, became a recognized leader in STEM+C programming in Wisconsin and across the country. EMMET attracted the attention of other community-based organizations, sustained and continued to grow partnerships with them, and created new opportunities for expansion.

Using this Guide

This paper contains helpful guidelines for those wishing to create makerspace programs in their communities, including:

- guidelines for recruiting maker-mentors through area schools
- guidelines for collaborating with community-based organizations
- suggestions for maker-mentor training and programming
- suggestions for a variety of programming opportunities
- lesson plan templates for maker activities
- tips for sustainability of programming

Study Context

Wausau Area

The city of Wausau (pop. 39,000) is located in Central Wisconsin; it is the county seat of Marathon County, home to approximately 134,000 residents. Surrounded by lakes, woods, and hills, Wausau offers "a combination of big city amenities and small-town hospitality" (Wausau Central Wisconsin Official Visitor Guide, 2021).

Nearly one-third of Marathon County's economy is based on manufacturing. The remaining workforce is divided between service, healthcare, and industry. From dairy farming to grains and ginseng, agriculture is an extremely important industry for the area.

Manufacturing

Many manufacturing companies in Marathon County are desperate for engineers and skilled employees who are STEM literate. Recruiting qualified personnel is challenging, and the need to "grow our own" STEM workforce is vital to Wisconsin's economy. A recent survey conducted by Northcentral Technical College of six local major employers who hire software developer-related occupations revealed that requiring candidates to have degrees in a computer-related field leads to difficulty finding qualified candidates. Meanwhile, area high schools struggle to interest students in higher education and to get students to think of themselves as potential members of the technical, manufacturing workforce (Alcoa Foundation, n.d.; Jaschik, 2015). In informal observations, area science teachers often spoke about the lack of resources available (e.g., a school with a $500 science budget for the academic year) and how this discouraged students' participation with science. EMMET sought to motivate and steer youth to career pathways associated with science, computer technology, engineering, and math, leading to critical occupational areas across numerous industries in Central Wisconsin.

Northcentral Technical College

The centrally located Northcentral Technical College (NTC) served as a hub for the EMMET program. The college has over 190 program offerings, including 2-year associate degrees, one- and 2-year technical diplomas that provide concentrated hands-on-learning, and short-term certificates to improve job skills.

Located in NTC's Wausau campus, the state-of-the-art STEM Center was built to provide STEM education and resources for NTC and the greater community. The center promotes NTC's five transfer agreements to 4-year engineering and engineering technology degrees and brings together math, science, and technical program faculty for multidisciplinary academic support for students and cross-disciplinary faculty collaboration.

EMMET's Mobile Makerspace

Due to geographic barriers, many rural communities like Wausau have utilized mobile makerspaces, which lessen barriers caused by distance (Moorefield-Lang, 2015; Craddock, 2015). Based on the concept of bookmobiles from the early 1900s, mobile makerspaces are built on the idea that "if they can't come to us, we will go to them" (Moorefield-Lang, 2015).

To engage the rural communities of North Central Wisconsin in innovative STEM and computer technology learning, EMMET utilized NTC's pre-existing mobile makerspace, Mobile Emerging Technologies Trailer (METT). The trailer was used to travel to local community-based organizations and events (e.g., public libraries, county fairs, and youth clubs) and offer informal activities. Maker-mentors staffed the EMMET trailer, offering free, drop-in maker activities designed to build interest, confidence, and self-efficacy with STEM and computer technology content, skills, and habits of mind (Agency by Design, 2015).

Partnership Model: NTC and University of Wisconsin–Madison

EMMET was a collaborative effort between Northcentral Technical College and the University of Wisconsin (UW)–Madison. Faculty and staff at NTC were responsible for the direction and development of the STEM+C informal curriculum and the related training components of this project, and for coordinating NTC resources for the project as needed. Researchers at UW–Madison were responsible for collecting data and designing and supervising all aspects of the research process, including understanding the impacts of the EMMET programming for rural communities, and the longitudinal impacts of participation on the maker-mentor cohort. An external evaluator from UW–Madison directed the external evaluation of this project and was responsible for overall design, as well as data collection, analysis, and the reporting process.

Maker-Mentor Case Studies

Throughout this paper, we refer to the experiences of six maker-mentors. Table 1 displays their pseudonyms and how they described themselves at the start of the EMMET program.

Table 1. **Descriptions of the maker-mentors in this paper**

Pseudonym	Description of maker-mentor at the start of EMMET
Sarah	11th grade White female who described herself as curious, artistic, creative, and positive
Anna	10th grade White female who described herself as artistic, inclusive, organized, open-minded, and as a designer
Martin	9th grade White male who described himself as curious, dedicated, a problem solver, logical, and ambitious
Luis	10th grade Latino male who described himself as curious, dedicated, open-minded, and logical
Nick	10th grade White male who described himself as curious, open-minded, a teacher, ambitious, and positive
Brad	9th grade White male who described himself as curious, dedicated, open-minded, and logical

Impact on Rural Communities

EMMET was designed to value existing community assets by working with pre-existing community-based organizations (hereafter, CBOs) and events. Because EMMET was mobile, making experiences could be brought to places where community members already gather, and facilitated by young people who were also members of the community. Training local teens to staff the mobile makerspace helped establish credibility and sustainability for the makerspace in a rural community. This approach also ensured that maker activities would be more innovative and equitable, as opposed to dropping the activities into already established social and cultural education routines (Halverson & Peppler, 2018).

Partnering with Community-Based Organizations

Six community-based youth organizations enthusiastically agreed to participate in EMMET. Each organization dedicated a staff member to participate in the teacher preparation component and help coordinate logistics for EMMET programming. The CBOs that served the project's targeted communities were:

(Two) Boys & Girls Clubs: The Boys & Girls Club of Wausau serves over 5,500 youth annually in the Wausau and Weston communities. The Boys & Girls Club of Langlade County serves over 2,600 youth annually in the Antigo community. Boys & Girls Clubs offer a space for youth (ages 7–18) to engage in a range of programming opportunities year-round, including programs on education, careers, character and leadership, arts, sports and recreation, and health and life skills. Clubs are highly accessible and well established in their respective communities; they serve youth and families at low or no cost, removing financial barriers to participation.

(Three) Public Libraries: Marathon County Public Library's nine branches serve 20,208 students annually throughout Marathon County. Two branches located in the Wausau and Mosinee communities partnered in this project. Antigo Public Library, located in the Antigo community, serves over 2,400 students annually. The libraries' physical spaces, programming, and services promote and support lifelong learning and provide equitable access to ideas, information and opportunities to connect with others. The three libraries are staffed with designated young adults/teens who provide a range of targeted programming for middle–high school aged youth.

University of Wisconsin–Extension Langlade County 4-H, located in the Antigo community, serves over 300 youth annually. A youth development program of the Cooperative Extension System and U.S. Department of Agriculture, 4-H is offered to community youth during out-of-school times. 4-H offers science programming that provides youth the opportunity to learn about STEM through fun, hands-on activities and projects. 4-H also offers the STEM Career Pathway, an easy-to-follow, 4-step framework for exploring, learning, practicing, and experiencing STEM careers. Focus areas for 4-H science programs include: robotics, rocketry, environmental science, agri-science, biotechnology, and veterinary science.

Creating Co-learning Experiences for Young People and Their Families

EMMET events took place onsite at the technical college's STEM Center, at local community-based programs, and at large-scale community events including parades, county fairs, and a Hmong heritage festival. The events all featured maker experiences designed over the course of the project. These designed experiences were divided into three types: short exposure activities (5–15 minutes), extended skill-building activities (90 minutes), and long-term, community-driven maker activities (weeks-long).

Exposure Events

Exposure events were designed to introduce STEM concepts to large numbers of people in an interactive format. Key ideas of these exposure activities are illustrated and discussed within the framework of computational thinking. These activities were designed to be utilized in a drop-in format and to last between 5–15 minutes. Learners typically did not produce an artifact to take with them. Table 2 summarizes the full range of exposure activities.

Table 2. **Summary and description of exposure activities**

Exposure Activity	Description
Fruit Piano/ Makey Makey	Makey Makey circuits are connected to fruits that, when touched by a participant, make sounds like a piano.

Exposure Activity	Description
3D Printer	3D printers are displayed and operated to print numerous 3D items, including 3D cats.
Whack-a-mole	Makey Makey circuits are connected to multiple pieces of Play-Doh. Participants play a game where moles that pop up on the screen correspond to different pieces of Play-Doh. “Hitting” the Play-Doh acts as the control mechanism for hitting the moles on screen in the game.
Mario	Mario, a classic Nintendo video game, is played using Makey Makey as the controller, where circuits are connected to Play-Doh.
Squishy Circuits	Any number of activities that allow users to create electronic circuits using conductive and insulating Play-Doh.
Sphero	A programmable robot controlled by a phone or tablets.
Ozobot	A robot that uses basic programming concepts and can follow lines, colors, and codes on physical surfaces.
Vegetable & Fruit Conductivity	Makey Makey circuits and an LED are connected to fruit or potato to demonstrate conductivity and electricity.
“Walk on Water”	Using Oobleck—water and cornstarch—to introduce the basic concept of dilatant fluids and how they change with and without force.
Self-inflating Balloons	Putting balloons filled with baking soda onto a water bottle containing vinegar; experiment exposes young learners to solid, liquid, and gas properties by expanding a solids volume with a gas caused by a chemical reaction.
Augmented Reality Sandbox	An augmented reality sandbox that allows learners to shape sand, augmented by an elevation map that simulates mountains and water. The visual is then represented in real time on a television monitor.

Skill-Building Activities

Skill-building activities were designed to be conducted with a group of learners who have dedicated time to participate. Activities typically last 90 minutes and were designed for learners to complete a project such as creating electronic wearables with conductive thread or designing cards using paper circuitry. In total, EMMET maker-mentors offered and facilitated 56 skill-building activities from August 1, 2018–July 31, 2019. Events ranged from a 4-hour activity at Antigo Library, where maker-mentors helped young makers create a greeting card that used paper circuitry, to a 3-hour activity at the 4-H program, where young makers designed and built popsicle cars with an electric motor.

Extended Making Events

Extended events were long-term, community-driven emergent projects. The goal of these activities was for maker-mentors to design and carry out their own project. Maker-mentors participated in a series of maker activities including the creation of their own Star Wars themed parade float and costumes for a local holiday parade.

A Closer Look at Exposure Events

Exposure events offered an introduction to STEM+C activities for community members of all ages. While each exposure event was unique and varied by attendees and activities offered, we share two different examples. The Langlade County Fair represents an exposure event contained in the EMMET trailer. The Wausau Science & Engineering Festival represents an on-site exposure event that was able to take advantage of all the resources available at the NTC STEM Center. Both offer insights into how community members experienced these drop-in making experiences. Exposure events were successful at:

- sparking curiosity, interest, and excitement of STEM+C activities for community members of all ages
- encouraging co-discovery within family units
- allowing for the exploration of new technologies
- allowing for interest-driven discovery
- initiating constructivist behavior that could be encouraged further through additional supports from maker-mentors
- serving as a pathway into scientific thinking and learning outcomes outlined in the Next Generation Science Standards (NGSS)

Sparking Curiosity, Interest, and Excitement

Positioned just outside the trailer during the Langlade County Fair, the 3D printers and water balloon activity drew in both young kids and their parents. Novel activities spark curiosity, promote exploration (Cors et al., 2018), and are often appealing and attractive to learners (Anderson & Lucas, 1997). Visible and accessible materials also encourage tinkering and new ideas (Peppler, 2016).

At the fair, the initial spark from these exposure activities often led visitors to explore other maker activities, ask questions, and learn basic STEM or computational concepts from 1–2 activities. This process resembles interest-based learning, which recognizes that learners are more motivated to learn when they have an invested interest in the content (Rusk, 2016; Larson & Rusk, 2011). The most popular activity was the augmented reality sand table, located inside the trailer. The sand table allows learners to mold sand in a physical sandbox, which is then projected via a special 3D scanner to a television screen, creating a map with elevation, topographic lines, and water.

The event held at the Wausau Science & Engineering Festival generated similar enthusiasm. Many learners shared emotional reactions to their time at the STEM Center. They wrote about activities that were "really cool" or that they "really loved." Several learners punctuated their comments with smiley faces ":)," and learners were especially excited to watch the 3D printer. As one learner described, "So the 3D printer was so cool, I learned that the stuff that's made from a 3D printer is plastic!" Additional information on how we interpret the value of these comments as evidence of interest in STEM and computational thinking is available in our forthcoming journal publication, "'I played a song with the help of a magic banana': Assessing short-term making events" (Nixon et al., in press).

Encouraging Co-discovery

Families often explored the trailer and activities together. Young visitors and guardians took turns trying out the equipment. Most often, kids started playing with an activity. This led to four different reactions: Guardians would 1) ask their children questions, 2) try to help, 3) ask the facilitators questions, or 3) get involved and start participating in the activity together.

Allowing for the Examination of New Technologies

During the Wausau Science & Engineering Festival, learners expressed their growing understanding of new technologies and grappled with the complexities of technology and human intervention. Many participants described their activities as if their being present had little to do with how the making activities functioned. They often positioned themselves outside the action. For example, in writing about the Makey Makey fruit piano, they said the following: "Fruit piano. We saw how fruit plugged into a computer makes music," and "my fav. thing was seeing what the 3D printer was making." [1] However, learners also treated the Makey Makey piano and Whack-a-mole activities as autonomous tools, as if their presence had little connection with how technologies functioned. Examples included, "Fruit piano we saw how fruit plugged into a computer makes music," and "I learned that fruit, vegetables, and Play-Doh can make electricity and 3d printers can make anything you want."

Other learners described a feeling of working with the tools to produce something. Most often, this meant creating music with bananas and pianos. Comments such as, "I made some Beats on The Banana," recognize the banana as something the learner used to create music, while learner comments such as "The banana sends electricity through your body," give the tool much more agency than the learner. Examples such as, "I participated in the banana piano. When I didn't have the banana it wouldn't play because it wasn't complete," demonstrate an understanding of the relationship between the banana and the visitor as both being necessary components in creating sound. While the purpose of our work was not to critically examine the relationship between humans and technologies, we found that this discussion was at the forefront of participants' experiences.

[1] All learner comments are printed verbatim, not corrected for spelling or grammar.

Allowing for Interest-Driven Discovery

At both events, visitors could choose their path, stopping to work or moving quickly through each activity, depending on their interest or time available. Most visitors moved fairly rapidly from activity to activity, spending 1–5 minutes at each activity, but others stayed longer, including one young maker who spent over 30 minutes diving into each activity. Some older makers visited twice: they started exploring with their guardians and returned later to spend more time programming the remote-control cars.

The level at which learners participated in activities varied. The five most popular verbs learners used to describe their experiences were *see*, *watch*, *play*, *make*, and *do*. Three of these verbs—play, make, do—suggest an active experience. The most common verb used to describe participation at the Wausau Science & Engineering Festival was "saw" or "watched." This verb was often used to describe the 3D printer, but was also used to describe activities that required learners' participation, such as the Makey Makey piano and Whack-a-mole.

Initiating Constructivist Behavior

A few learners' responses reflect constructivist behaviors. Constructivist behaviors are those where learners generate or create a product beyond the materials originally provided (Chi & Wylie, 2014). Examples include comments such as "I made a light turn on," and "I created a working circuit to power a fan with Play-Doh." While only a few responses suggested constructive behaviors, we can see how short-term events can allow enough time for learners to gain new knowledge through their experiences working with an activity.

Creating Pathways Into Scientific Thinking

Many learners made sense of their experiences by trying to understand how things worked. Learners explored how the 3D printer worked by breaking it down into smaller, more manageable parts. The comments, "I learned that the stuff that's made from a 3D printer is plastic," and "The 3D printing dinosaurs look metallic, but feel stringy," show visitors' attempts to explain how the 3D printer works.

Several learners described their experience in terms of scientific language, using vocabulary such as "conductivity" and/or "electricity" to explain how activities functioned. The example, "I participated in the banana piano. When I didn't have the banana it wouldn't play because it wasn't complete," shows a maker trying to explain their knowledge of basic circuitry. Other examples of the use of scientific language to explain their experiences include: "[I learned] that bananas can make music with conductile," and "I learned that fruit can conduce electricity to play a piano." Learners also came to understand the function of electricity writing: "My favorite thing was the fruit piano because I like electricity and it's cool how the fruits can conduct," and "I learned that you can create light without electricity."

Creating Extended Community-Based Learning Experiences

Each year, Wausau hosts a holiday parade that features local businesses and organizations. During the second year of the program, EMMET had the opportunity to create a float and walk in the holiday parade to highlight and advertise the program. The staff asked the maker-mentors to brainstorm and determine a theme for their float. Almost unanimously, the maker-mentors decided on Star Wars.

The Star Wars float was one of the long-term collaborative projects in which the maker-mentors engaged. It was also their favorite project. This is not surprising, as allowing young makers to choose their projects can be a powerful motivator (Blikstein, 2008). Making artifacts for the float required maker-mentors to call upon their creativity and use available tools and resources to create an artifact of importance and relevance to the local community. The project forged an important bond between the maker-mentors as they continued to develop into a community of practice (Wenger, 1998).

Thus, through the creation of the Star Wars float, maker-mentors engaged in interest-driven learning; leveraged community-based resources to gain new skills; leveraged pre-existing assets to create an artifact of importance to their community; and built a community of practice through sharing knowledge with their peers and teaching one another new skills

Engaging in Interest-driven Learning. In addition to choosing the theme of Star Wars, the maker-mentors were free to choose *what* they made. One group chose to create lightsabers, one group decided to create an R2-D2 robot, and another chose to make Jedi robes for the entire team.

The lightsaber team was unsure where to start, so they looked up directions online, made a shopping list, and asked one of the adult staff members to take them on a shopping trip to pick up materials from the local hardware store. After purchasing items they'd not previously worked with, such as acrylic plastic tubes and a vacuum hose, they used the available tools in their makerspace—a soldering iron, screw drivers, hammers, and hack saw—to create a new artifact.

Leveraging Community-Based Resources. Sarah, Anna, and one additional female maker-mentor chose to create Jedi Robes for their whole team. Because the adult facilitators did not have experience with sewing, they brought in a local seamstress. The area seamstress served an integral role in the success of the project.

The maker-mentors had material and sewing machines, but were not sure where to start. As Sarah began sifting through the material, an adult staff member told her she needed to have a pattern. Sarah replied, "but I don't know how to sew!" The area seamstress explained that they could find patterns online and Anna grabbed a computer to look for a pattern they could use for Jedi robes. They found a pattern, printed it out, and the seamstress showed Anna how to use a rotary cutter to cut out the patterns. Finally, the seamstress helped the maker-mentors learn how to use the Brother sewing machines.

Similar to previous research on rural makerspaces, we found that leveraging community resources was essential to the success of this project (Kim & Copeland, 2020; Horton, 2017). The act of bringing in a local seamstress created a purposeful connection between maker-mentors and a valued community resource. The impetus for the project was also community-minded. Maker-mentors walked among more than 50 local businesses and non-profit organizations, sharing their work as part of a local tradition—the community's holiday parade.

Leveraging Pre-existing Assets and Sharing Knowledge. Martin and Nick joined two other maker-mentors to create a model of R2-D2. For this project, they were able to build upon their pre-existing assets. As members of their school's robotic club, they previously worked together building a robot for a VEX competition. Nick had taught himself how to program and served as the programmer for the VEX competition. He was able to share this knowledge with his team to design the R2-D2. First, they created a 3D design, then used a laser cutter to cut wood pieces that could be assembled later. Nick succeeded at learning the new software (SolidWorks) to design the model R2-D2. Martin said that prior to EMMET, one of his favorite creations was the robot for the VEX competition. He was able to leverage his passion for planning, designing, building, and programming in the multi-layered R2-D2 project.

Although neither Anna nor Sarah knew how to use a sewing machine, Sarah started to teach herself from the manual that came with the machine. She quickly figured out how to thread and insert a bobbin by using instructions included with the machine. She noticed that Anna was having difficulty threading the bobbin and moved over to Anna’s machine to help, asking “so, you know what a bobbin is, yes?” When Anna replied no, Sarah described and demonstrated the process she had just learned herself.

Building a Community of Practice. Maker-mentors’ funds of knowledge helped them use their expertise to connect to new knowledge and experiences. Moll et al. (1992) define funds of knowledge as “the historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning and well-being” (p. 133). The funds of knowledge concept has been used to characterize thriving maker communities and to understand the culture and practice of rural learning communities (Coggin, 2017). During the creation of the Star Wars float, Sarah—who was artistic and creative—considered how the costumes, lightsabers, and R2-D2 would be designed and integrated physically into the float for visual effect. Costume design allowed Sarah and Anna to leverage their assets to serve the larger group. Martin and Nick used their previous experience with engineering and computational thinking to determine how to break down all of the smaller parts necessary to create the R2-D2. They brought their programming skills to a new, more complex creation. In turn, they taught each other new skills.

From costumes to lightsabers, each part of the project benefitted the larger group. Sewing machines and laser cutters held equal importance for the success of the project. Maker-mentors’ reliance on each other and shared interest in the project helped forged relationships that further solidified the community of practice (Sheridan et al., 2014; Wenger, 1998).

Maker-Mentor Experience

Maker-Mentors: A Unique Approach

As an integral part of the programming, we recruited high school maker-mentors and trained them to facilitate making events throughout the community. Maker-mentors were paid for their time, following the success of science museums across the United States that employ high school-aged “explainers” in their making spaces (e.g., the New York Hall of Science and the Science Museum of Minnesota). EMMET aimed to professionalize maker-mentors and to value their contributions as knowledge workers. Maker-mentors that completed programming were eligible to receive an NTC STEM Leadership certificate, providing formal recognition of skills and knowledge gained through earned credits.

Recruitment of Maker-Mentors

Before: Getting Buy-In. The Dean of Engineering and Advanced Manufacturing at NTC established lines of communication to build collaboration with local schools, libraries, after-school programs, and community educational organizations. The Dean met with school principals and administrators to outline the scope of the project, gauge interest and capacity for participation in EMMET, and describe how the project might benefit the students in the district as a whole.

The curriculum development team contacted faculty and teachers at area schools that had some connection with STEM+C educational contexts, including extracurricular clubs or STEM courses offered in the schools, such as engineering or drafting, and set up an informational meeting to outline the scope and purpose of the EMMET project and gauge interest in the program.

Flyers were posted around the school the week before, announcements were made throughout the week prior to the event, and staff and teachers made sure to communicate with any prospective students.

During: Holding Recruitment Events. The curriculum development team facilitated maker-mentor recruitment events at seven area schools that indicated interest in the program. These events were held at each participating school campus on a school day during lunch and study halls; the visits were arranged with teachers and school faculty. Each of these awareness events lasted approximately 1 hour and covered programmatic goals: establishing STEM+C mentorship sites in the respective communities; roles and responsibilities of maker-mentors; and types of events and activities.

An average of 10–20 students attended each event. The EMMET team brought several pieces of the EMMET trailer equipment as well as the materials the maker-mentors would have access to, including laptops, Arduino software, microcontrollers, and other devices.

Student interest forms were handed out at the events and collected from students approximately two weeks later, for review and selection.

After: Choosing the Maker-Mentors. Every student filled out an interest form after the EMMET leadership team pitched the project at their schools. If more students were interested than could have been accommodated in the program, the leadership team planned to use these forms to determine who they would select. This was not necessary, as 20 students submitted interest forms and the project could accommodate 20 student maker-mentors and 12 adult maker-mentors.

Additional Recruitment. Through the course of the program, 37 maker-mentors participated in EMMET. Some were recruited at the start of the program and remained through the two years, while others joined later or did not continue to the end of the program.

Maker-Mentor Demographics

Maker-mentors came from three school districts: D.C. Everest Area School District (5,900 students total), Marathon County (731 students total), and Langlade County (2,300 students total). At the start of the program, the cohort was predominantly male (70%). While this is disappointing relative to the program designers' interest in disrupting the male culture of making, STEM, computer science, and engineering, the number of self-identified female participants in our cohort (30%) is higher than the 24% representation in STEM fields reported by the Economic and Statistics administration in 2017, and higher than female representation in computer science and engineering undergraduate programs at the largest university in Wisconsin, where women comprise only 13% of graduating computer science majors and 21% of engineering graduates (Schneider, 2018).

The maker-mentors were also predominantly 10th and 11th grade students, all of whom attended local public high schools (including two public charter schools) across two adjacent counties. Demographics regarding race and ethnicity are relatively in keeping with those for the broader area. The maker-mentor cohort self-reported at 20% non-White, which is consistent with U.S. Census data on non-White residents for the area (21%). This percentage is slightly above the 12% non-White student enrollment at the partnering technical college, NTC. In reviewing the data, we noted the intersectional identities of some of the cohort members. For example, several who reported as Latin@ were also female. Finally, we noted that a large majority of the White male participants came from a single school on the west side of the largest participating community, which was also the best funded community and the location of the technical college.

Maker-Mentor Training

Bi-monthly Skill Building Workshops Through NTC

Throughout the course of the EMMET program, maker-mentors received training from three entities: Northcentral Technical College, Science Museum of Minnesota, and the Children's Museum of Pittsburgh. At monthly training workshops at NTC's STEM Center, maker-mentors learned STEM+C skills and improved their facilitation skills. High school teachers and CBO staff were also invited to participate in the training workshops. Maker-mentors also used this time to collaborate and build with their peers for larger group projects. During the first year of the program, 16 maker-mentors travelled to the Science Museum of Minnesota for a 2-day training. During the second year, 21 students and adult maker-mentors participated in an all-day facilitation training provided by the Children's Museum of Pittsburgh. Finally, in July 2019, 15 maker-mentors participated in a 4-day training in Pittsburgh at the Children's Museum. Through all of these experiences, maker-mentors experienced programming and training that covered a variety of topics. Table 3 provides a general overview of the materials, concepts, and content provided in trainings by the three organizations.

Table 3. **Content of maker-mentor trainings**

Organization	Content and themes addressed	Materials/ tools introduced or available during trainings
Northcentral Technical College, monthly trainings	Learn new activities and work with new materials; recognize the importance of STEM+C; create and plan activities to facilitate in	Arduinos, micro bits, laser cutting, craft cording, pliers, beads, conductive thread, LEDs, batteries, glue guns, plastic tubing, 3D

Organization	Content and themes addressed	Materials/ tools introduced or available during trainings
	community; collaborate on long-term making projects; coordinate and organize details for upcoming facilitation events	printer, Makey Makey products, circuits
Science Museum of Minnesota	Historical and social context of making; STEM+C justice and equity; knowing yourself as a learner; growth versus fixed mindset; developing criteria for maker activities; creating a mission statement; identifying project goals	Introduction to wearables and digital screen printing
Children's Museum of Pittsburgh	Maker learning practices; design process; facilitation methods (simple interactions method), informal learning practices and set up; recognizing STEM+C in society	Variety of materials available for creating and making (plastic bottles, pipe cleaners, copper tape, LEDs, cardstock, etc.), Cricut cutters

Skills Developed Through Maker-Mentor Program

Throughout the program, maker-mentors gained a variety of new skills. They learned how to use new tools or materials, gained an understanding of STEM+C, and improved their collaborative and interpersonal skills. These skills were rooted in the three overlapping components of the maker-mentor model: learn new skills, facilitate events, and grow within a community of practice.

Learning to Use New Tools and Repurpose Materials. Throughout the EMMET program, maker-mentors were introduced to and had the opportunity to use new tools and work with a variety of materials. Although maker-mentors entered EMMET with varying levels of familiarity with maker tools and artifacts, their prior knowledge of these materials did not necessarily dictate their continued participation or success in the program, as all methods of making were equally valued.

For example, Nick and Martin entered the program with extensive prior experience with coding and building robots. Sarah entered the program with minimal coding experience. Anna had no coding experience, but gained some during the program. Sarah and Anna acquired the greatest number of new skills and experience working with new tools as a result of their participation. Nick and Martin continued to build on skills they acquired before the EMMET program, using prior coding experience to master new programs, such as SolidWorks. Luis, who stated that he had never made anything prior to the program, acquired new skills such as programming LEDs. Table 4 provides a full list of skills and experience with tools mentors entered with and gained during the program.

***Table 4.* Maker-mentor skills before and during time in EMMET program**

Mentor	Skills before entering program		Skills gained through program
	Favorite thing they made	**Tools maker-mentors stated they used/know how to use**	**Tools maker-mentors stated they used/know how to use**
Sarah	"A puzzle cube that I 3D printed"	"A little [coding] but not that much;" Art and design tools, including an unspecified CAD program	Making a circuit board, coding, sewing, programming robots, sewing machine, squishy circuits, Cricut machine, repurposing items for new purposes
Anna	"A thrown bowl made out of clay"	None specified	Coding, Arduinos & Makey Makey, sewing and sewing machine, LED circuitry, squishy circuits, Cricut machine, wood cutting with laser cutter and with hand saw, repurposing items for new purposes
Martin	"A robot for this year's VEX competition"	Coding, Arduinos and tools necessary to create a simple quadcopter	Cricut machine, wood cutting with laser cutter and with hand saw, repurposing items for new purposes
Luis	Claimed "I haven't constructed or made anything" but later referenced building a bridge in class	"Wood and stuff" required to build a model bridge in an engineering class	Coding on Pi Tops, programming LEDs, repurposing items for new purposes
Nick	"A robot for the robotics competition this year"	Programming: Scratch, C#, Unity; soldering, circuit boards	Microcontrollers, Arduino, CAD software: SolidWorks & Fusion 360, repurposing items for new purposes

Understanding STEM+C. Maker-mentor's understanding of STEM+C shifted from the beginning to the end of the program. Early in the program, for example, Sarah indicated computational thinking as an important new skill in her "tool box," before offering this description: "It's kind of like um—it helps because it's like bouncing off ideas and different things that you can like—it's the problem-solving thing that you can use. I guess? I don't know." At the end of the program, Sarah's understanding was more robust. During a group training, she explained that computational thinking has four parts and then applied this knowledge of decomposition to describe a group making project.

The mentorship program helped maker-mentors recognize the clear connection between science, technology, engineering, math, and computational thinking. Sarah explained it as follows: "So there's like the STEAM part of it and science is only one of the components. But you can't just look at one you kind of have to look at them all because you can't do just science. It's got to be science and math and all the other stuff."

Many maker-mentors mentioned creativity when talking about STEM+C. Sarah, who often cited her art and design skills as the basis for being a part of EMMET, explained the project to outsiders this way: "I don't know it's about like, another bunch of meetings on how to be creative and how to like spread the creativity I guess and like how to teach kids to work and make."

Sharing STEM+C With Community Members. All the maker-mentors believed that it was important to help their community by sharing their knowledge of STEM+C. Luis recognized that as students who recently learned the same content, they would be able to better connect with the younger audience. They all described STEM+C as integral skills that are essential for their contemporaries. Nick explained that "getting kids involved younger makes them more susceptible to having better ideas and more open mindedness later in life. So doing this where we get to go around and just teach the public kids and adults about STEM ideas is interesting and I think it will be helpful to our community."

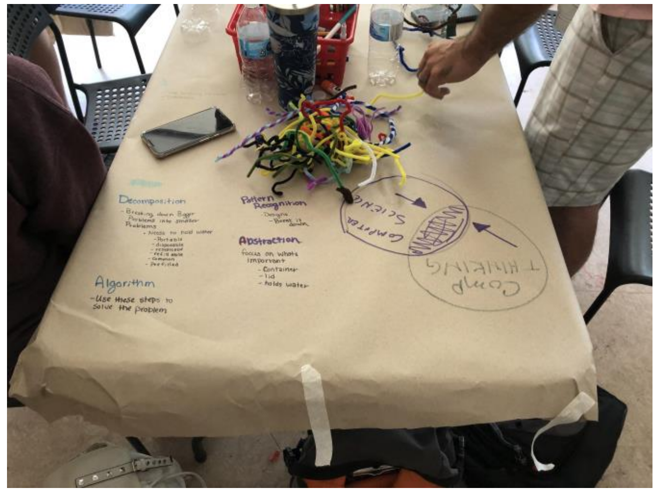
Case Study 1: Sarah

Sarah was a creative and confident junior in high school who described herself as curious, artistic, creative, and positive. Sarah worked a part-time job at a craft store and played in the pep band. She joined EMMET because she was interested in being part of a community and because she enjoyed designing, producing, and seeing projects from start to finish. Sarah's parents and teachers encouraged her to apply to the program to find out if she enjoyed engineering, and to nurture her creative and artistic skills in a new way.

As a method of assessing incoming maker-mentors' interest and expertise, we asked everyone to draw a picture of something they would like to make. Instead of drawing a picture, Sarah wrote the following: "I'm not 100% sure on the resources available but I'm excited to learn what they are and what I can make from them."

Sarah entered EMMET with a "little bit" of coding experience. Throughout her time as a maker-mentor, she learned more about art and design tools, including an unspecific CAD program, as well as how to make a circuit board, code, sew, program robots, and use a variety of other tools and materials for repurposing new materials.

Sarah, who often cited her art and design skills as the basis for being a part of EMMET, often spoke of STEM and computational thinking specifically in connection with creativity. Explaining EMMET to outsiders, she said: “I don’t know it’s about like, another bunch of meetings on how to be creative and how to like spread the creativity I guess and like how to teach kids to work and make.”



Sarah found that what she liked most about STEM+C was solving problems. For this reason, she imagined going into a career like architecture, where she could solve problems and design solutions. She explained that she liked the idea of “something where someone comes and goes hey we want to build this but like we don’t know what to do and I’d be like, oh I have some ideas like different things like that. Like water parks or like just parks in general.”

After graduating from high school, Sarah began taking classes at Northcentral Technical College and enrolled in welding courses in her first year.

Decomposition: Breaking Things Down Into Smaller Parts. Maker-mentors learned how to break down problems into smaller parts through decomposition, an integral component of computational thinking. This new understanding helped them in their everyday lives beyond the scope of EMMET, including in their own learning and work.

For example, Nick described that his experience with EMMET helped him in his math class: “When I’m doing like math or anything I do a lot of the work in my head and so I’ve started to kind of write down what I’ve been doing and stuff like that.”

Nick also used this same tactic when helping his friends in math class. He mentioned that before EMMET, he did not know how to explain math problems because he always solved them in his head, so he would say “you just write this equation and then you just solve it,” and found that this approach did not work. EMMET helped him explain his steps so that others could understand.

Sarah found that her experience with EMMET helped her in her job as a swim instructor and in mentoring her younger brother. She suggested that while she had always known how to solve problems through breaking them down into smaller parts, “EMMET kind of like opened up your mind to it and kind of makes you think about it more.”

Learning about decomposition was nurtured through facilitating making activities to younger learners, through writing out lesson plans that had several working and integrated parts, and through ongoing conversations about STEM+C during trainings where maker-mentors constantly evolved their understanding of these concepts.

Throughout EMMET, maker-mentors worked with senior personnel and adult mentors to create lesson plans for 25 new STEM+C activities. Creating lesson plans required maker-mentors to detail the step-by-step process needed to teach the content, list potential problems that might evolve and methods for troubleshooting, list materials and objectives for the activity, and explain directions multimodally using both text and image. The process of creating lesson plans further developed the maker-mentor's ability to break things down into smaller parts, to think about facilitation methods, and to improve upon their ability to provide directions. (See Appendix for an example of a typical lesson plan on creating binary jewelry).

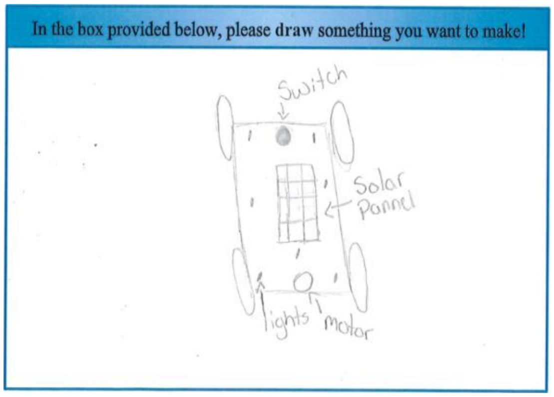
Improving Collaboration and Teamwork Skills. Maker-mentors improved their inter-personal communication and collaborative skills through co-facilitating events for younger makers. Co-facilitating events required them to take on different roles to ensure everyone the same chance to participate, while valuing that each maker-mentor needed a different amount of time to get comfortable teaching different skills. They learned about new tools from watching and teaching with their peers; they had time to become comfortable with a tool before moving into the lead teaching position; and they learned how to improvise, react to, and build on their peers' actions. For example, a maker-mentor who was not leading an activity had to focus on the instructions while preparing and handing out materials.

Maker-mentors also improved their collaborative skills through participation in multiple collaborative making activities. Many maker-mentors spoke about how they came to value collaboration and co-production for challenging their ideas—allowing them to bounce ideas off one another, learn new skills, and improve their practice. Anna explained that with EMMET, collaboration felt relaxed and natural, as opposed to other situations she had experienced.

Luis explained the importance of working toward a common goal: "EMMET has helped me interact with other people, share my ideas, and actually create things. You know, with other people, we're all working together towards a goal—and just interact with other people I like—I like doing that stuff, and it's helped me become better at it."

Case Study 2: Anna

At the start of the program, Anna was a sophomore who described herself as artistic, inclusive, organized, open-minded, and a designer. Anna was a member of the volleyball team, church youth group, and Girl Scouts. She joined EMMET because she thought "it would be a cool opportunity to learn and help others learn at the same time." When asked to draw a picture of something she'd like to make, Anna drew a picture of a solar operated car.



Anna learned how to use a variety of new tools and materials throughout the program (from coding, Arduinos and Makey Makey, to sewing and using a sewing machine). More than anything, Anna spoke about how EMMET helped her move out of her comfort zone to meet new people:

"I don't like to go outside my boundaries even though like I need to, so going into EMMET, there's only one other person from my school and I didn't really know her and so I had to meet kids from other schools who knew each other...so that way just getting used to being uncomfortable. I like the phrase being comfortable with being uncomfortable."

Anna also constantly improved her ability to break down complex processes and explain steps in a way that was manageable for younger students. She shared, "I have learned a lot from doing or even training all the stuff—so I know a lot more personally and I can see it and I have like an eye and I feel like...you just kind of like...see like there's a bigger picture like this something is working, but so much goes into it."

During one of the trainings at the Children's Museum of Pittsburgh, all the maker-mentors were tasked with creating a representation of computer science using a water bottle and any other available materials. Anna created a robot. She explained her artifact as follows: "I put a dress on it to give us a color and I named it Sierra, which stands for sympathetic intelligent experiment robot research and atoms...just basically computer science vocabulary. But I wanted it to be nice, that's why it's sympathetic."

Since graduating from high school, Anna started college at an in-state university and is majoring in psychology. Outside of school, she participates in a psychology club and works in a job where she often has to train her colleagues.

Reflecting a year after the end of the project, Anna explained that her experience in EMMET taught her how to communicate and solve problems. The experience for Anna was one of self-discovery. She shared that "I have also learned that I don't really care for much of the technology side of STEM and that is okay and I am glad to have had the experience and say that I learned how to code. I would do EMMET again if I had the opportunity because I got to do so many cool things and learn so many things about myself that I would never had known if I didn't get this opportunity."

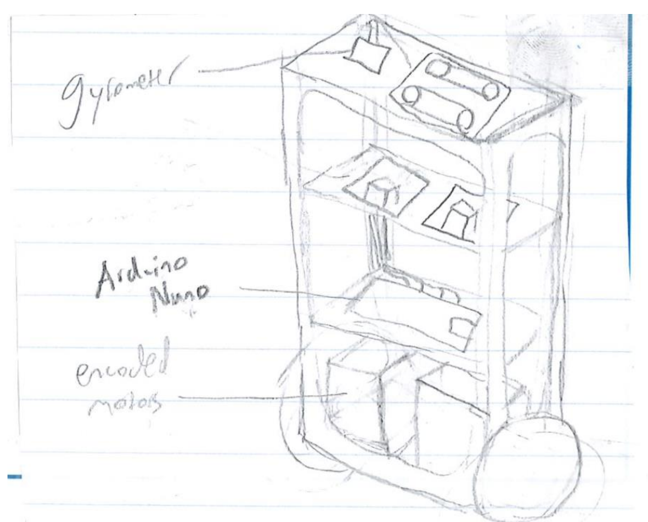
Becoming Better Teachers and Improving Communication Skills. Many of the maker-mentors mentioned becoming better teachers through their time in EMMET. They had numerous opportunities to gain interpersonal skills by working together and facilitating events in their local community. Sharing knowledge and skills with younger makers allowed maker-mentors to move from novice to expert as they transferred activities they learned about in training sessions and then taught the same content to others. Through facilitating activities, maker-mentors continuously tried new things, learned from their experiences, and iteratively improved their explanations. Mentors described that while they previously would show young makers what to do, they began to see that it is important for them to tinker first, and figure it out on their own.

While some maker-mentors were ready to take the lead early, others had plenty of time to gain confidence. Because maker-mentors taught in groups, each person could assume more and more responsibility based on their comfort level. Sarah was able to expand her skills when she felt ready to do so. Anna, who was more reserved and preferred one-on-one instruction, was able to gain confidence before leading a whole group lesson. Toward the end of the program, Sarah explained that, “I realize that like at first I sit back but like now I know everybody in my group so now I’m like, I’m comfortable to explain and stuff.” Anna explained that the opportunity to work one-on-one with younger makers helped her improve her ability to break down complex processes and explain steps in a way that was manageable for younger students.

Sarah was able to transfer what she learned about facilitating making events to her job as a swim instructor. She described that at the start of EMMET, “I’d probably be like, oh you do this and this and this...but now I realize that you have to let them kind of like explore and create.” After facilitating multiple making events she explained that she altered her swim instructions to have kids explore and see what they can do on their own before offering tips or instructions.

Case Study 3: Brad

At the start of the program, Brad was a high school freshman who described himself as curious, dedicated, open-minded, and logical. He was involved in several extracurricular activities including cross country, curling, track, and the robotics club. He also worked at the local planetarium and served as an usher in his church. He joined EMMET because he loved STEM+C subjects and programming microcontrollers, and because his friends and family told him he was good at explaining things to people. When asked about something he would like to make, Brad drew a self-balancing robot.



Reflecting on his time in the program, Brad explained what EMMET meant to him: “At the time I was in Emmet, I was devolving into anti-socialness, but I think Emmet helped me keep from irreversibly falling into it. Also...Emmet has/will definitely help me in applying to jobs, colleges, etc.”

After the EMMET program, Brad continued to follow his love for STEM+C subjects by taking Calculus II & III and Physics I & II, developing software for a local manufacturing company, and competing in Science Olympiad, all during his senior year in high school. While applying for colleges, Brad intended to study either industrial engineering or physics.

Self-Discovery. The EMMET program offered opportunities for maker-mentors to learn more about their interests, try out new things, and learn more about their own preferences. For example, Anna shared that “EMMET just helped me figure out things I didn’t like and things I did like to help me think about what I want for the future.” Luis came to realize that he enjoyed more hands-on making activities over programming. Sarah learned that she loved problem solving, while also finding new ways to integrate her passion for art and creativity into STEM+C.

Area for Growth: Maker-Mentors on the Peripheral

Two maker-mentors, Luis and Nick, did not participate in EMMET as fully as the other maker-mentors. Both entered the program with knowledge of STEM+C similar to their peers, and both attended training sessions the first year but attended fewer facilitation events than the other maker-mentors. While Nick and Luis had multiple responsibilities outside of EMMET that might have caused their lower attendance, they both revealed additional challenges. Nick revealed that he gravitated towards non-physical making, even though community events prominently featured physical making. “I’m not like mechanically inclined to make like— I’m not—I don’t like mechanical engineering, there we go.” Nick also had a unique relationship with his peers and sees himself situated outside of the group in terms of intelligence: “I view everyone here as smarter...like more intelligent, I guess, than me so I kind of try to sometimes—I try to go higher than I can and that makes me go down more, so I just—it’s kind of like a interpersonal struggle kind of sometimes.” In interviews with Luis, he rarely talked about his relationship with other maker-mentors or about his connection with the group itself. Luis was the only person of color that continued with the program during the first year.

Yet both Nick and Luis described their favorite moments in EMMET in terms of working with others. Nick shared that his favorite memory was an experiment where the maker-mentors made Oobleck, a non-Newtonian fluid of cornstarch and water that acts like a liquid when being poured, but like a solid when pressure is applied. He explained that this “was the best EMMET training I've had and probably the best experience...because I just got to interact with more people than I normally do.”

Maker-Mentors’ Post-Secondary Trajectories

All the maker-mentors saw their experience with EMMET as a pathway toward a future career, although they had different ideas about what those future careers would be. Table 5 displays each mentor’s future career plans toward the end of their participation in the program.

***Table 5:* Maker-mentor career plans**

Sarah	*Architecture* or, "something where someone comes and goes hey we want to build this but like we don't know what to do and I'd be like, oh I have some ideas like different things like that. Like water parks or like just parks in general"
Anna	*Uncertain*, but stated that, "EMMET just helped me figure out things I didn't like and things I did like to help me think about what I want for the future"
Martin	*Electrical engineer*, like his father
Luis	*Uncertain*, but wrote that he planned to use STEM+C skills in his future career
Nick	*Professor,* but also recognized that "any STEM skill will give you a good job and a good future in general"

The maker-mentors who entered with confidence about their STEM related training—Martin and Nick—had clear ideas about their career paths. Martin, for example, knew STEM was important because his father was an engineer and he planned to follow in his father's footsteps. Nick also came into the program confident about his future career, and aspired to be a professor.

Sarah and Anna entered the program to find out more about available career paths. Sarah's parents and teachers encouraged her to apply to the program to find out if she enjoyed engineering, encouraging her creative and artistic skills in a new way. She imagined going into a career like architecture, where she could solve problems and design solutions. Although Anna was uncertain about her future career, she shared that "EMMET just helped me figure out things I didn't like and things I did like to help me think about what I want for the future." Luis knew that he planned to use STEM+C in his future career, but did not know what that career would be or what skills or tools exactly he enjoyed the most.

Sustainability and New Opportunities

As EMMET ended, many of the maker-mentors were preparing for summer vacation or for college. During the summer of 2019, maker-mentors gathered once more at the STEM Center for a closing ceremony, where they shared their maker lesson plans with the CBOs, transferred STEM kits to the CBOs, and were honored with a STEM Facilitator Certificate.

STEM Facilitator Certificate

Sixteen maker-mentors earned a STEM Facilitator Certificate at the end of the program. Requirements included maintaining an active status, participating in at least ten trainings at the NTC STEM Center, facilitating at least five events, completing and presenting a maker activity, and participating in at least two capstone trainings. The certificate involved a four-course curriculum worth six college credits, which can be applied to other STEM programs to showcase making in other disciplines at NTC, such as information technology, engineering, manufacturing, and allied health.

Table 6. **College credits per course for STEM Facilitator Certificate**

IT Development and Design Fundamentals	1 credit
Introduction to STEM	1 credit
Introduction to Microcontrollers	1 credit
Technical Reporting	3 credits

The STEM Facilitator Certificate is available today as a 5-credit course for K–12 educators or CBOs. The coursework includes Introduction to STEM, Facilitating Events, and one of the following: Teaching Science, Teaching Math, or Teaching Technology and Engineering. NTC will continue to offer this certificate and will promote it to various entities and individuals. The first group will most likely be a cohort of middle-school teachers; two non-profit organizations have expressed interest for their staff, and the NTC's Workforce Training & Professional Development team will explore possibilities with businesses, especially those known to support STEM.

Empowering Community-Based Organizations to Facilitate Making Experiences in Their Learning Spaces

At the end of the program, each CBO was given a toolkit of materials, including lesson plans for making activities created by the maker-mentors, so that the CBOs could continue to provide the same type of programming in their learning environment. Table 7 lists the physical resources in the toolkits.

Table 7. **Contents of toolkit**

Materials	Quantity
iPads	6
iPad Cases	6
Chrome Books	6
MKE Cases	2
Sphero	6
Ozobots	6
Little Bits	2
Makey Makey	6
Squishy Circuit Deluxe	6
Cricut Maker	2

Making Spaces

The staff at NTC worked diligently to continue the momentum of the program, forming the Central Wisconsin STEM Leadership Committee. Bringing together 45 leaders from the CBOs and new members such as the Wausau Chamber of Commerce, the team sought to combine efforts, share resources, and coordinate STEM activities throughout the region.

Based on the success of the EMMET program and the relationship between NTC and local CBOs, NTC was chosen to participate in the 2020–2022 Making Spaces program (https://makered.org/making-spaces). Making Spaces is a partnership led by Maker Ed and Children's Museum of Pittsburgh with the goal of sustainably integrating making into learning environments across the country (Maker Ed, n.d.). NTC is one of the first two technical colleges in the nation to participate in the program, and part of the first Making Spaces cohort focusing on rural communities.

As a regional hub, NTC builds the local infrastructure and implements and supports maker-centered learning programs at local CBOs and schools. The CBOs and schools, in turn, build and implement their programs. Through Making Spaces, NTC was able to continue working with several CBOs from the EMMET program and build new relationships with area schools and additional organizations such as the Chamber of Commerce.

New Opportunities

NTC's experience with EMMET and growing reputation throughout the STEM community led to additional opportunities for both the college and young people in the community. In 2021, NTC will serve as a pilot site for the Michigan Tech Mind Trekkers Unboxed Challenge.

Recommendations for Rural Maker Programming

This research suggests several lessons that may be adapted to similar programs:

Train local high school maker-mentors to facilitate making events. Focus training on facilitation methods first, and tools second. The benefits of training high school students as maker-mentors are two-fold: the program 1) offered learning opportunities for teen maker-mentors, and 2) helped grow a locally-based maker program. We recommend focusing initial training on facilitation techniques, and offering maker-mentors several opportunities to practice and reflect on facilitation techniques before introducing additional tools.

Create interest-based projects for maker-mentors to work with community members, and foster relationships among maker-mentors. Maker-mentors who built strong relationships with their peers were more likely to finish the program. These relationships can be forged through long-term projects tied to their community.

Capitalize on exposure activities to introduce making and STEM+C to community members of all ages. The exposure activities were successful in introducing STEM+C in a fun environment that promoted family-based inquiry. This initial spark can lead to further exploration into STEM activities.

Position maker-mentors at all activities during exposure events, and prepare them to use facilitation techniques. To ensure that learners have the opportunity to have the most enriching experiences at each of the activities, it is essential for maker-mentors to assist in helping young learners build a bridge between old and new knowledge, creating more opportunities for constructive behaviors. While there were no maker-mentors present at the 3D printers during the STEM Days, we suggest that additional mentors or guides should be positioned near the printers to ask and answer questions, provide information about the 3D printer, and share information about how 3D printers are being used in meaningful ways in science, engineering, and artistic endeavors.

Leverage and build off pre-existing community resources. EMMET staff leveraged community assets by bringing in area experts to teach new skills and integrating EMMET activities into pre-existing community events. This allowed for EMMET to be highly visible to the community and for community members to consider EMMET as a part of their larger community.

Build a sustainable partnership that can withstand staff turnover. Throughout EMMET, from the design stage to the end of the program, our staff fluctuated. NTC's initial principal investigator accepted another position and a new faculty member took over. Several other staff at NTC and UW–Madison also changed positions. This fluctuation created setbacks and realignment of goals, and required involved parties to shift priorities several times. Turnover is common in technical colleges and research institutions, where graduate students enter and leave programs on a regular basis. In a project of this size, it is essential to have 1–3 core members to shepherd the program from beginning to end. Throughout EMMET, one full-time staff member was in charge of reaching out to area schools and educators to advertise the program and coordinate events and schedules with local CBOs. At the start of the program, this role mostly involved getting the word out, but towards the end of the program, there were many requests that could not be fulfilled as there were not enough maker-mentors to fulfill all of the requests. Subsequently, this staff member's role grew drastically. For similar programs, it is necessary to have at least one full-time staff member whose sole role is coordinating events and communicating with outside organizations.

Next Steps: Areas for Growth

This research revealed areas for growth and continued research:

Focus maker-mentor training on facilitation techniques and then integrate the learning of specific tools into programming. At the start of the EMMET program, much training focused on providing maker-mentors the skills needed to operate particular tools. While these skills are necessary to help others learn the same tools, they may be moved further in the training schedule to prioritize learning facilitation techniques. Moreover, training can combine facilitation techniques and the learning of tools so maker-mentors can gain both skills simultaneously.

Explore possible facilitation techniques for exposure events and place maker-mentors at each station, poised with a toolkit of techniques to engage learners. Maker-mentors can be particularly helpful in guiding young makers' learning at exposure events. This type of guiding requires a unique type of facilitation that can be integrated into the maker-mentor trainings. Moreover, while maker-mentors were positioned at most of the exposure activities, they should also be positioned at each station, including the 3D printer, to help young makers learn more about this tool.

Examine community impact through additional research. Additional research is needed to fully understand EMMET's impact on community members' perception of and interest in STEM+C learning and careers. Impact is difficult to measure, particularly during exposure events, as community members enter and exit the mobile makerspace so quickly. Understanding the full extent of impact on the community will require additional longitudinal data collection and analysis.

Examine the impact of EMMET for Community-Based Organizations through additional research. Several Community-Based Organizations started their own maker programming using tools provided at the end of the EMMET program, and several more are still connected to NTC through the Making Spaces program. Interviews with CBO leaders can provide a fuller picture of how EMMET impacted their organizations.

Hire diverse staff and ensure a variety of making activities at skill-building events. While there were a variety of factors surrounding Luis and Nick's low attendance at facilitation events, factors can be addressed to remove barriers for students in similar programs. Specifically, programs can create more trainings for maker-mentors on gaining facilitation skills so they feel comfortable in these events; facilitators can create varied opportunities for maker-mentors to work with a variety of peers in fun and exploratory ways to encourage continued relationship-building among maker-mentors; and program coordinators can eliminate barriers for students by hiring diverse adult staff and mentors that are in line with maker-mentors' cultural and racial identities, and by varying the types of making activities at facilitation events.

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Appendix

Exposure Activity Lesson Plan

Binary Jewelry

Purpose: Structured Informal STEM+C Skill Building Maker Activity
Introduce participants to ASCII binary code—without computers!
Introduce the basic concepts of computational thinking.
Decomposition: Breaking a task into to smaller parts
Pattern recognition: Looking for things that are the same
Abstraction: Finding what is important and what is not important
Algorithmic Design: Creating step-by-step instructions

Required Items

- Craft cording, clasps, jump rings, pliers, seed beads
- It would be beneficial to have clasps, jump rings, and crimps pre-attached to the craft cording

Procedure (60 Minutes)

- ❖ Introduce Activity –10 Minutes
  - ➢ Describe activity using examples
    - ■ Outline the Process for the Activity
      - ● Learn about computer code and ASCII
      - ● Learn about developing a design process (Computational Thinking)
    - ■ Discuss Learning Objectives
      - ● What is binary?
      - ● How do computers use it?
    - ■ Pattern Recognition - Matching
      - ● Discuss with the group. Use this to discuss design procedure
    - ■ Abstraction – Thoughts and Ideas
      - ● Discuss with the group.
      - ● Capture group discussion using available media (whiteboard, easel pad, etc.)
    - ■ Algorithmic Design –What's the Plan
      - ● Discuss with the group. Using the captured media from the above CT concepts work out a plan
      - ● What things need to be accomplished in each step before proceeding to the next step?
- ❖ Begin the design procedure reinforcing the learning objectives

- Let individuals proceed at their own pace with "challenges"
- Show and Tell
  - Discuss with the group. Revisit previous discussion.
    - Capture group discussion using available media (whiteboard, easel pad, etc.)
      - What did we learn about?
      - What would be a good idea to change?
      - What was hard to understand?
      - What could we add to the activity?

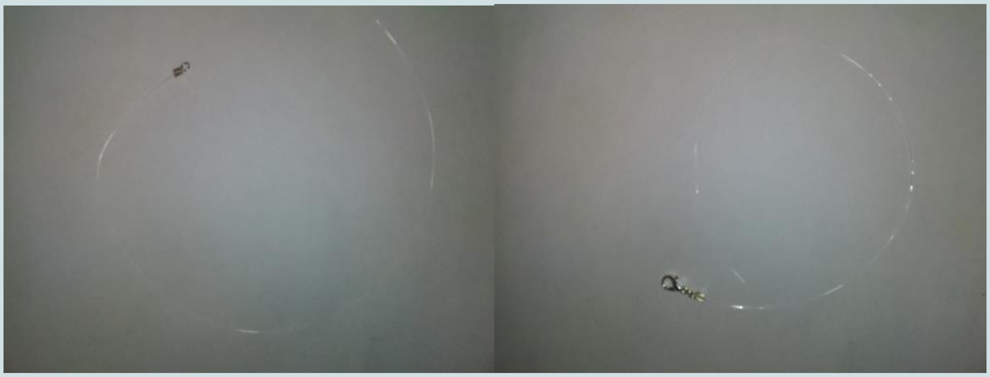
Step 1: Picking Colors

Decide what you are going to spell out and pick three colors. Assign one of the colors to ones, one to zeros, and one to spaces between letters and words. Write everything down.

Step 2: Setting up the Project

Cut enough craft cording to wrap around your wrist 1 ½ times.

Use the pliers to bend a jump ring and attach it to a clasp. Thread one end of the craft cording through one side of a crimp tube, add the jump ring that you just attached to a clasp. Thread it through the other side of the tube and crimp it. Thread the craft cording through the ending crimp, and use the pliers to crimp.



Write out what you want to say, then transfer each letter to code using the ASCII Binary Alphabet Chart.

ASCII BINARY ALPHABET

A	1000001	N	1001110
B	1000010	O	1001111
C	1000011	P	1010000
D	1000100	Q	1010001
E	1000101	R	1010010
F	1000110	S	1010011
G	1000111	T	1010100
H	1001000	U	1010101
I	1001001	V	1010110
J	1001010	W	1010111
K	1001011	X	1010111
L	1001100	Y	1011001
M	1001101	Z	1011010

Start beading! For spaces between letters, use one bead. For spaces between words, use three. Use an additional five space beads at the beginning and the end of your message. Tie the second jump ring onto the end of the bracelet or necklace. For a keychain, knot the end.